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Computer aided flow sheet design for fine ore circuits

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ABSTRACT

With the increasing importance, complexity and therefore investment for the fine ore benefication circuits, the optimal design of the circuit is of paramount importance. This paper outlines a computer package developed at Indian School of Mines, with research grants from DAE and AICTE, to interactively design any complex flow sheet for the fine ore beneficiation circuit, after the grinding circuit, when the mineral characterstics and process performance parameters have been established earlier through laboratory tests, pilot scale studies and/or performance evaluation of similar operating plants.

SET UP DATA

The data on mineral characterisation and performance parameters form the basis of the design and are stored earlier in a data file commonly referred to as the fixed data file or set up data file.

An example of such a set up data file is given in Table 1. The set up file contains the following data in the prescribed format.

1. The names of the propoerties considered, the names of the mineral components and the quantitative values of the properties.
2. The names of the equipment/processes, the names of the design and operating parameters of each of them and the range of values each one of them can take.
3. At the end of the partition value of each of the mineral in each process for the optimum conditions established by experiments.

This file, though in ASCII format for ease of updating, must not be altered except by the authorised experts. The package can be adopted for any other fine ore circuit by suitable alteration of this set up data file. For example the set up file required for a lead zinc circuit is given in Table 2.

Table 1 : Set up data for beach sand beneficiation plants

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	Number of properties	= 4			
1	Size in mm.				
2	Density in gm/cc				
3	Magnetic susceptibility as % of iron				
4	Electrical conductivity as % of rutile				
	Number of minerals	= 7			
1	Ilmenite	0.177	4.2	7	80
2	Rutile	0.143	4.1	0.5	100
3	Monazite	0.078	5.1	2	2
4.	Zircon	0.102	4.7	0.5	1
5	Sillimanite	0.216	3.2	0.5	3
6	Garnet	0.371	3.7	3.5	5
7	Quartz	0.229	2.7	0.5	2
	Number of processes	= 10			
1	High tension rolls (Non cond. cleaner)				
	250	150	350	Roll diameter in millimeters	
	200	50	450	Roll speed in r.p.m.	
	75	25	200	Gap of electrode in millimeters	
	24	50	10	Voltage in kilovolts	
	1	5	.2	Feed rate in t.p.h. per meter length	
	45	100	5	Cutter pos. (Cleaner/Scavenger etc.)	
2	High tension rolls (Cond. cleaner)				
	250	150	350	Roll diameter in millimeters	
	200	50	450	Roll speed in r.p.m.	
	75	25	200	Gap of electrode in millimeters	
	24	50	10	Voltage in kilovolts	
	1	5	.2	Feed rate in t.p.h. per meter length	
	45	100	5	Cutter pos. (Cleaner/Scavenger etc.)	
3	Magnetic rolls (Nonmag. cleaner)				
	250	450	150	Roll diameter in millimeters	
	150	450	30	Roll speed in r.p.m.	
	15000	3000	22500	Field strength in gauss	
	150	300	75	Poll gap in millimeters	
	1	.2	5	Feed rate in t.p.h. per meter length	
	45	3	100	Cutter pos. (Cleaner/Scavenger etc.)	
4	Magnetic rolls (Mag. cleaner)				
	250	450	150	Roll diameter in millimeters	
	150	450	30	Roll speed in r.p.m.	
	15000	3000	22500	Field strength in gauss	
	150	300	75	Poll gap in millimeters	
	1	.2	5	Feed rate in t.p.h. per meter length	
	45	3	100	Cutter pos.(Cleaner/Scavenger etc.)	

(contd.)

Table 1 (contd.)

5	Humphrey Spiral concentrator			
	18	28	15	Angle of gradient of the spiral
	42	48	15	Feed pulp density in % of solids
	30	3	60	Feed pulp rate in cubic meters/hour
	60	75	3	Wash water rate in cubic meters/hour
	6	3	7	Number of spigots for heavies
	45	3	100	Spigot open. (Cleaner/Scavenger etc.)
6	Xatal Spiral concentrator			
	10	8	15	Angle of gradient of the spiral
	25	22	30	Feed pulp density in % of solids
	30	3	60	Feed pulp rate in cubic meters/hour
	31.5	15	50	Wash water rate in cubic meters/hour
	6	5	19	Number of spigots for heavies
	11	5	19	Spigot open. (Cleaner/Scavenger etc.)
7	HG-8 Spiral concentrator			
	19	8	25	Angle of gradient of the spiral
	25	22	30	Feed pulp density in % of solids
	30	3	60	Feed pulp rate in cubic meters/hour
	0.05	0.1	0.01	Wash water rate in cubic meters/hour
	4	1	4	Number of spigots for heavies
	4	1	4	Spigot open. (Cleaner/Scavenger etc.)
8	Sand screen			
	.5	1	.2	Aperture size in millimeters
	.3	.1	.5	Wire diameter in millimeters
	2	1	2	Opening (Square 2 rectangle 1)
	30	180	6	Residence time in seconds
	0	0	15	Angle of inclination
	0	1.2	0	Water spray cubic meter/tonne
9	Wet table			
	1.5	.5	3	Feed pulp rate in t.p.h. per square meter
	12	2	20	Inclination of the deck in degree
	23	20	30	Feed pulp density % solid
	1.2	.2	2.0	Wash water rate in cubic meters/hour
	72	60	80	No. of strokes/minute
	670	79	1370	Splitter/cutter position
10	Readings throw off rolls (N. mag. cleaner)			
	150	200	1500	Roll diameter in millimeters
	150	150	120	Roll speed in r.p.m.
	14000	12000	14000	Field strength in gauss
	6	25	3	Poll gap in millimeters
	2	1	4	Feed rate in t.p.h. per meter length
	75	200	0	Cutter position in mm.

(contd.)

Table 1 (contd.)

Eq.	Index	1	2	3	4	5	6	7
1	.55	94	97	2	1	1	7	1
2	−.55	6	3	98	99	99	93	99
3	−.55	95	1	15	1	1	45	1
4	.55	5	99	85	99	99	55	99
5	−.34	93	89	97	95	18	22	2
6	−.34	93	89	97	95	18	22	2
7	−.34	93	89	97	95	18	22	2
8	0	100	100	100	100	100	100	100
9	−0.5	96	94	99	98	6	8	1
10	−.55	98	8	70	1	1	90	1

Table 2 : Fixed data for the design of lead zinc ore circuits

Warning : DO NOT EDIT THIS FILE WITHOUT PROPER AUTHORITY

	Number of properties	= 3		
1	Reference size in mm.			
2	Density in gm/cc			
3	Flotability without depressant as percent of galena			
	Number of minerals	= 4		
1	Galena	0.15	7.0	98
2	Sphalerite	0.15	4.6	92
3	Pyrite	0.125	5.1	84
4.	Rest	0.1	2.7	26

Number of processes = 6

1	Lead rougher flotation circuit			
	0.29	0.05	0.8	Collector–xanthate kg/tonne
	0.07	0.03	0.2	Frother Pine oil kg/tonne
	0.31	0.8	11.0	Depressant NaCN in kg/tonne
	8.12	6.0	11.0	Basicity/acidity in pH
	32.0	10.0	45.0	Pulp density solid percent by weight
	4.5	1.5	12.5	Residence time in minutes
2	Lead cleaner flotation circuit			
	0.3	0.05	0.8	Collector–xanthate kg/tonne
	0.07	0.03	0.2	Frother Pine oil kg/tonne
	0.3	0.8	0.1	Depressant NaCN in kg/tonne
	8.1	6.0	11.0	Basicity/acidity in pH
	28.0	6.0	45.0	Pulp density solid percent by weight
	4.5	1.5	12.5	Residence time in minutes

(contd.)

Table 2 (contd.)

3	Lead scavenger flotation circuit			
	0.3	0.05	0.8	Collector–xanthate kg/tonne
	0.07	0.03	0.2	Frother Pine oil kg/tonne
	0.3	0.8	0.1	Depressant NaCN in kg/tonne
	8.1	6.0	11.0	Basicity/acidity in pH
	35.0	12.0	45.0	Pulp density solid percent by weight
	4.5	1.5	12.5	Residence time in minutes
4	Zinc rougher flotation circuit			
	0.15	0.03	0.7	Collector–xanthate kg/tonne
	0.03	0.02	0.2	Frother Pine oil kg/tonne
	0.3	0.05	0.9	Activator $CuSO_4$ in kg/tonne
	9.7	7.0	12.5	Basicity/acidity in pH
	25.0	12.0	45.0	Pulp density solid percent by weight
	4.5	1.5	12.5	Residence time in minutes
5	Zinc cleaner flotation circuit			
	0.15	0.03	0.7	Collector–xanthate kg/tonne
	0.03	0.02	0.2	Frother Pine oil kg/tonne
	0.3	0.05	0.9	Activator $CuSO_4$ in kg/tonne
	9.7	7.0	12.5	Basicity/acidity in pH
	25.0	12.0	45.0	Pulp density solid percent by weight
	4.5	1.5	12.5	Residence time in minutes
6	Lead scavenger flotation circuit			
	0.15	0.03	0.7	Collector–xanthate kg/tonne
	0.03	0.02	0.2	Frother Pine oil kg/tonne
	0.3	0.05	0.9	Activator $CuSO_4$ in kg/tonne
	9.7	7.0	12.5	Basicity/acidity in pH
	25.0	12.0	45.0	Pulp density solid percent by weight
	4.5	1.5	12.5	Residence time in minutes

Eq.	Index	1	2	3	4
1	–.56	64	7	3	2
2	–.53	60	3	3	2
3	–.55	66	8	3	2
4	–.55	46	63	4	3
5	–.56	32	57	4	3
6	–.54	43	68	4	3

Table 3

Set up file used = class. set
Number of sizes = 5; Number of sources = 1
Tailing of CUP for Garnet and Sillamanite

Size mm.	D. % p.	Ilmeni	Rutile	Monazi	Zircon	Sillim	Garnet	Quartz
0.500	15.80	7.59	0.63	0.00	0.63	3.16	55.69	32.30
0.300	8.30	13.30	1.20	0.00	0.00	9.60	48.20	27.70
0.250	55.80	4.10	0.40	0.00	0.20	24.70	28.50	42.10
0.150	18.60	5.90	0.50	0.50	0.50	31.70	12.40	48.50
0.106	1.50	33.30	0.00	0.00	6.70	13.30	13.30	33.40

Table 4

Set up file used = Lead zinc. set
Number of sizes = 5; Number of sources = 1
Experimental data

Size mm.	D. % p.	Galena	Sphale	Pyrite	Others
1.000	2.00	2.50	2.40	4.00	91.10
0.500	12.00	2.90	2.80	4.00	90.30
0.212	50.00	3.60	3.10	3.70	89.60
0.075	25.00	7.00	4.50	2.20	86.30
0.037	11.00	8.00	4.90	2.10	85.00

Table5

The unit operations available are :

1 High tension rolls (Non cond. cleaner)
2 High tension rolls (Cond. cleaner)
3 Magnetic rolls (Nonmag. cleaner)
4 Magnetic rolls (mag. cleaner)
5 Humphrey spiral concentrator
6 Xatal spiral concentrator
7 HG–8 spiral concentrator
8 Sand screen
9 Wet table
10 Readings throw off rolls (N.mag. clean)
0 mixing or blending
– Sign and number of steps for recycle

For node number 1 type the serial number of the process/unit.

Table 6

Process number 1	Magnetic rolls (Mag. cleaner)			
	Input	Outputs :	2	3
Flow rate –	100.00		78.17	21.83
Ilmenite	6.19		0.49	26.58
Rutile	0.52		0.66	0.01
Monazite	0.09		0.11	0.03
Zircon	0.40		0.52	0.01
Sillimanite	21.17		26.78	1.11
Garnet	31.21		20.33	70.15
Quartz	40.42		51.11	2.11

For first stage of the unit operation, Type – 1 to delete this unit !
Select parameter by number 1 to 6. Type 0 to confirm all parameters.

	Present value	Minimum	Maximum
1 Roll diameter in millimeters	250.00	450.00	150.00
2 Roll speed in r.p.m.	150.00	450.00	30.00
3 Rield strength in gauss	150000.00	3000.00	22500.00
4 Poll gap in millimeters	150.00	300.00	75.00
5 Feed rate in t.p.h. per meter length	1.00	0.20	5.00
6 Cutter pos. (Cleaner/Scavenger etc.)	45.00	3.00	100.00

Give choice between 0 and 6

Table 7

Feed data from file tail. cup 13 unit operations in the flow sheet – Recv. of Gr. II silli from CUP TAIL

Code	<----Inputs---->					<–outputs–>			<---------- Process papameters ---------->											
4	1	15	24	0	0	2	3	0	150.00	120.0	22500.0	75.0	2.00	90.0	0.0	0.0	0.0	0.0	0.0	0.0
1	3	7	10	0	0	4	5	6	350.00	200.0	75.0	24.0	1.50	45.0	250.0	200.0	75.0	24.0	1.0	45.0
–1	5	0	0	0	0	7	0	10	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	6	0	0	0	0	8	9	0	150.00	120.0	22500.0	75.0	2.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0
–4	8	0	0	0	0	10	0	10	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	2	14	0	0	0	11	12	13	150.00	120.0	20000.0	80.0	2.0	90.0	250.0	150.0	15000.0	150.0	1.0	45.0
–1	12	0	0	0	0	14	0	10	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
–7	11	0	0	0	0	15	0	10	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	13	0	0	0	0	16	17	18	19.00	30.0	55.0	0.01	4.0	4.0	19.0	25.0	30.0	0.05	4.0	4.0
0	16	17	0	0	0	19	0	0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4	23	0	0	0	20	21	22	155.00	14.0	75.0	24.0	2.0	60.0	250.0	200.0	75.0	24.0	1.0	45.0
–1	21	0	0	0	0	23	0	10	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
–12	20	0	0	0	0	24	0	10	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Number of unit operations in this flow sheet = 13

	Process	<--------Inputs------>			<----Outputs---->		
4	Magnetic rolls (mag. cleaner)	1	15	24	2	3	
1	High tension rolls	3	7	10	4	5	6
–1	Recycle	5			7		
4	Magnetic rolls (Nonmag. cleaner)	6			8	9	
–4	Recycle	8			10		
3	Magnetic rolls (Nonmag. cleaner)	2	14		11	12	13
–1	Recycle	12			14		
–7	Recycle	11			15		
7	HG-8 spiral concentrator	13			16	17	18
0	Mixing	16	17		19		
2	from CUP TAIL rolls (cond. clean)	4	23		20	21	22
–1	Recycle	21			23		
–12	Recycle	20			24		

Table 8

Number of unit operations in this flow sheet = 13

	Process	<----Inputs---->					<–outputs–>		
4	Magnetic rolls (Mag. cleaner)	1	15	24	0	0	2	3	0
1	High tension rolls (Non cond. cleaner)	3	7	10	0	0	4	5	6
–1	Recycle	5	0	0	0	0	7	0	10
4	Magnetic rolls (Mag. cleaner)	6	0	0	0	0	8	9	0
–4	Recycle	8	0	0	0	0	10	0	10
3	Magnetic rolls (Nonmag. cleanrer)	2	14	0	0	0	11	12	13
–1	Recyle	12	0	0	0	0	14	0	10
–7	Recycle	11	0	0	0	0	15	0	10
7	HG–8 spiral concentrator	13	0	0	0	0	16	17	18
0	Mixing	16	17	0	0	0	19	0	0
2	Higfh tension rolls (Cond. cleaner)	4	23	0	0	0	20	21	22
–1	Recycle	21	0	0	0	0	23	0	10
–12	Recycle	20	0	0	0	0	24	0	10

Stream	Rate	Ilmeni	Rutile	Monazi	Zircon	Sillim	Garnet	Quartz
1	100.00	62.	0.5	0.1	0.4	21.2	31.2	40.4
15	91.35	2.1	0.0	0.0	0.0	0.9	95.3	1.7
24	5.62	3.1	0.0	0.0	0.0	0.6	95.1	1.2
2	166.64	1.2	0.3	0.1	0.2	13.2	59.9	25.1
3	30.33	20.9	0.0	0.0	0.0	0..2	78.4	0.4
7	4.13	4.7	0.0	0.0	0.0	0.6	93.5	1.2
10	49.06	0.0	0.0	0.0	0.0	5.8	82.9.	11.3
4	11.83	53.5	0.0	0.0	0.0	0.3	45.6	0.6
5	4.14	4.0	0.0	0.0	0.0	0.6	93.4	1.2
6	67.55	0.0	0.0	0.0	0.0	4.3	87.4	8.3
8	49.07	0.0	0.0	0.0	0.0	5.8	82.8	11.3
9	18.48	0.1	0.0	0.0	0.0	0.1	99.5	0.3
14	11.82	0.7	0.0	0.1	0.0	1.8	94.1	3.4
11	91.36	2.1	0.0	0.0	0.0	0.9	95.2	1.7
12	11.83	0.7	0.0	0.1	0.0	1.8	94.0	3.4
13	75.27	0.0	0.7	0.1	0.5	28.1	17.0	53.6
16	25.50	0.0	1.9	0.4	1.5	47.2	31.8	17.2
17	3.39	0.0	0.6	0.0	0.3	47.9	30.3	20.9
18	46.38	0.0	0.0	0.0	0.0	16.1	7.8	76.0
19	28.89	0.0	1.8	0.3	1.4	47.3	31.6	17.6
23	0.94	35.3	0.0	0.0	0.0	0.0	64.7	0.0
20	5.63	3.1	0.0	0.0	0.0	0.6	95.1	1.2
21	0.94	35.3	0.0	0.0	0.0	0.1	64.6	0.1
22	6.20	99.2	0.0	0.0	0.0	0.0	0.7	0.0

DATA ON FEED ANALYSIS

In addition to the set up data the design program needs the data on the size analysis and size wise mineralogical analyses of the feed ore for the circuits. The more the number of size and smaller the ratio between the successive sieves the more accurate is the result. However the present package is limited to not more than 8 sieves. The minerals with respect to which the composition of each size fraction has to be determined is specified in the characterisation (set up) data set.

The package includes a program to assist the design engineer to enter the sieve analysis and mineralogical composition in an interactive manner. The data is stored in ASCII format for ease of correction of errors in data entry through andy standard text editor.

An example of such a feed data file is given in Table 3. The data refers to the tailing product of the concentrate upgradation plant of the OSCOM project of I.R.E. Ltd.

An example of a feed to the lead zinc flotation circuit (after grinding and classification) is given in Table 4.

THE DESIGN PROGRAM

The design program displays the names of the equipment / processes available, from which the designer has to select one option by typing the corresponding number. Table 5 shows an example of the display listing the choice equipment and processes available. This display is derived from the set up data given in Table 1.

Thereafter the program asks for the equipment dimensions, design variables and process (operation) parameters corresponding to the equipment and the process in addition to the stream numbers defining the flow pattern. An example of the display showing the current settings of the parameters and the corresponding results is shown in Table 6.

For each input of the design or operation parameters the program estimates and displays the flow rates and flow compositions of the corresponding flow streams on the basis of the feed compositon. In addition to the equipment / processes the choice includes blending and recycle operations.

During the interactive input of the design data on the basis of the results displayed on the computer monitor the designer has the following choices.

i) Change any one design/operation parameter at a time and see the result.

ii) Accept the current value of the parameters as final for the particular unit.

iii) Add another unit operation to the flow sheet.

iv) Delete the current unit operation.

v) Terminate the design session after (or without) saving the design in a disk file.

The flow sheet designed, along with the data on the process parameters, is stored in a data file in the format shown in Table 7.

THE SIMULATION PROGRAM

The simulation program, which is to be executed after the completion of the design, simulates the operation of the plant including the effect of the recycles. The results of simulation are stored in a data file an example of which is shown in Table 8. The result is preceded by a descriptive table showing the plant configuration in the same format as in Table 7.

CONCLUSIONS

The package has been successfully used for the concentration plants for beach sand minerals. The data and results shown in Tables 7 and 8 are examples of such use. Work is now in progress to extend its capability to design complete separation plants (Dry Mills) for the beach sand minerals. Adoption of the package for base metal ores and other fine ores (excluding the grinding circuit) needs only the development of the corresponding characterisation data file.

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